

Methane ionization chamber to search for spin-dependent dark matter interactions

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A liquid-methane ionization chamber is proposed as a setup to search for spin-dependent interactions of dark-matter particles with hydrogen.

Search for relic dark-matter particles (DM) and investigations of their properties are among the most challenging problems of modern astrophysics, cosmology and particle physics. Detection of DM particles will cast light on the structure and genesis of our Universe. Therefore a lot of experiments (see for example [1, 2, 3, 4, 5]) are aimed at detection of these DM particles today. In modern particle physics the lightest supersymmetric particle (LSP) neutralino is assumed to be one of the best DM candidate. The promising idea of LSP detection relies on rather weak, but not vanishing, spin-dependent (SD) and spin-independent (SI) interactions of the LSP with ordinary matter nucleus. In general, one believes that for heavy target nuclei the SI interaction dominates, but for light nuclei the SD interaction makes the dominant contribution to the expected event rate of DM detection (see for example [6, 7]). Furthermore, for rather light LSP the light targets are preferable kinematically. Therefore, to search for very light dark matter LSP, which are not yet completely excluded [8, 9], one have to use a light target nucleus and expect the SD interaction to dominate [10, 11, 12].

In this short note we describe a new special liquid-methane chamber [13, 14, 15, 16] which could be used to search for the DM particles, provided they are the lightest neutralinos. The proposed two-phase methane ionization chamber is shown in Fig. 1. The **Body** of the chamber is made of titanium. The **Cathode** of the chamber is immersed in liquid methane. The layer of liquid methane above the cathode is equal to 200 mm. The temperature of liquid methane is equal to 115 K and the pressure of gaseous methane over the liquid methane is equal to 1.3 bar for this temperature. The **Anode** of the chamber is placed in gaseous methane above liquid methane. The anode consists of a system of points. The **Focussing screen** is placed between the Anode and liquid methane. The screen has a system of holes [17] concentric on the relevant anode points (Fig. 2). The values of the electrical potentials on the electrodes of the chamber are determined in such a way that all electrical lines of force are focused on the

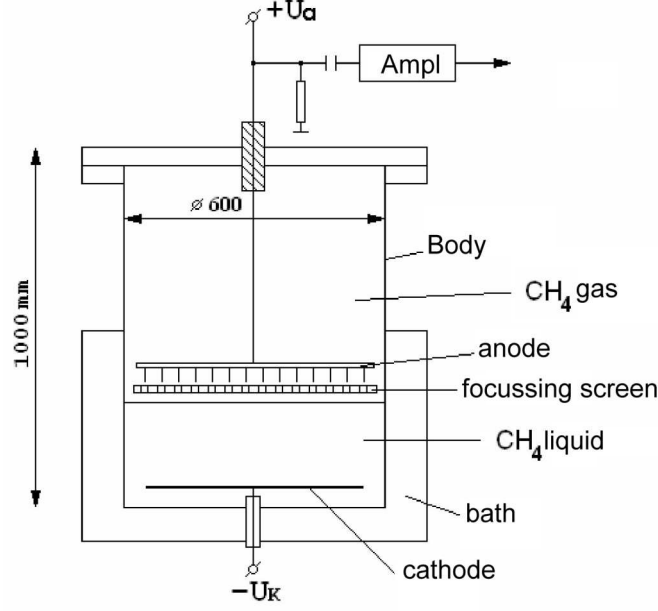


FIG. 1: Schematic view of the proposed two-phase methane chamber.

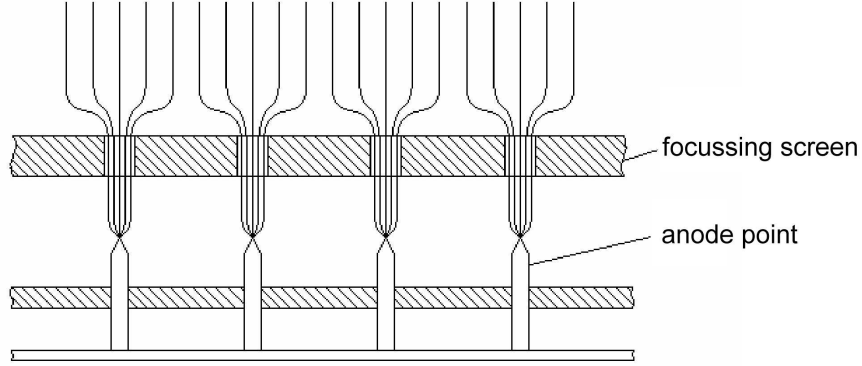


FIG. 2: System of focussing screen and anode points.

anode points.

It is necessary to point out that the method with point anodes and a focussing screen can be used in a liquid ionization chamber with the Anode and the screen placed immediately in the liquid medium. The proportional discharge was obtained in liquid argon ($K_{\text{ampl}}=100$) with the point anode $\sim 0.5\mu\text{m}$ in diameter at the end of the Anode in work [18]. A model of the detector was constructed for testing the work of the methane chamber with the anode points (Fig. 3). The W-wire with a diameter of $20\mu\text{m}$ is used as the point anode in this detector. The Pu^{239} α -source ($10^3\alpha/\text{s}$) is placed at the cathode. The electric field intensity varies as R^{-2} near the point anode, whereas in the cylindrical chamber it varies as R^{-1} . This allows a greater electric field intensity near point anode in semispherical geometry than in the cylindrical chamber. The maximum amplification factors obtained in the detector with different gases are

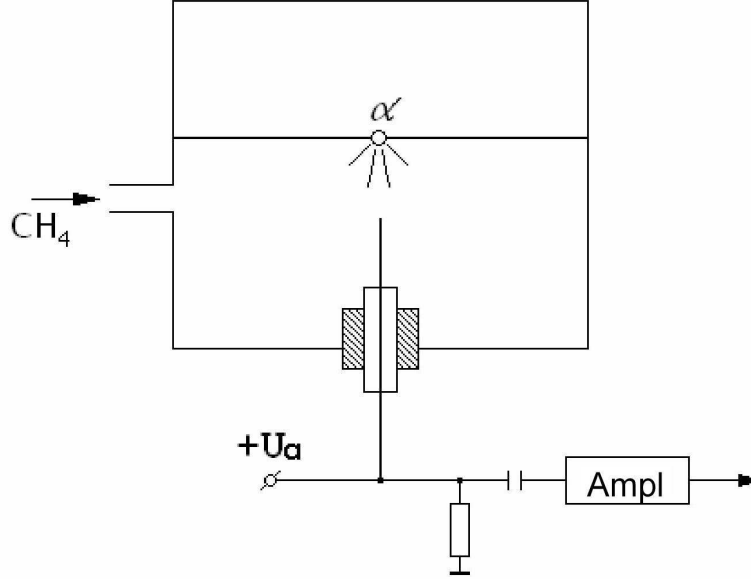


FIG. 3: Schematic view of the detector.

shown in Table I.

TABLE I: Amplification factors for different fillings of the detector.

| Gas | Pressure, kgf/cm ² | | | | |
|--|-------------------------------|------|------|------|-----|
| | 0 | 5 | 10 | 25 | 50 |
| H ₂ | 600 | | 600 | 300 | |
| H ₂ + 10%CH ₄ | 600 | | | 600 | 300 |
| CH ₄ | 4000 | 4000 | | 1000 | 600 |
| <i>n</i> -C ₄ H ₁₀ | | 4000 | | | |
| Ar+10%CH ₄ | | | 4000 | 2000 | |

The mean calculated energy of recoil hydrogen atoms after neutralino scattering is equal to ~ 1 keV, of which $\sim 80\%$ (0.8 keV) are spent for ionization [19]. One recoil hydrogen atom of 1 keV produces ~ 20 ionization electrons [20]. The amplitude of the signal at the point anode will be equal to $\sim 10^5$ electrons with the amplification factor $\sim 4 \cdot 10^3$ obtained in the model detector. This signal can be easily detected.

CD₄ can be used for filling the chamber instead of CH₄ [21]. In principle, CD₄ has the following advantages over CH₄. First, the energy of the recoil deuterium atom after neutralino scattering is some 2 times larger than for hydrogen. Secondly, the deuterium nucleus spin is $J = 1$ ($J = \frac{1}{2}$ for hydrogen nucleus). This could increase in general the spin-dependent cross section.

In conclusion, we give only an idea of using a specially designed liquid-methane ionization

chamber in an experiment aimed at searching for the (mostly) low-mass dark-matter particles on the basis of their spin-dependent interactions with hydrogen. Further simulations of all possible backgrounds are obviously necessary to make a conclusion as to real prospects of such a full-scale dark-matter experiment with liquid-methane ionization chamber.

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